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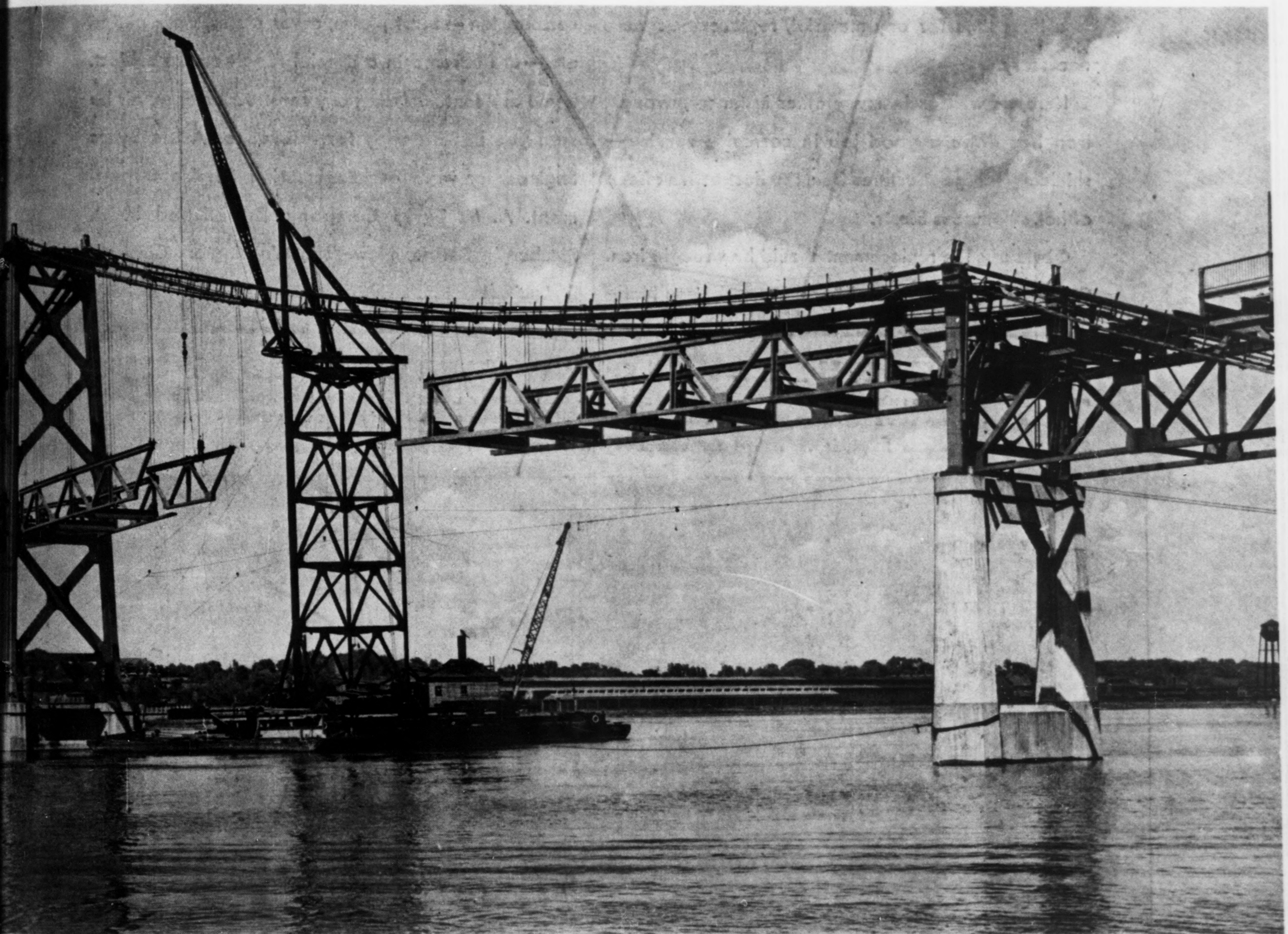

Stiffening truss erection by floating derrick on the Davenport Bridge over the Mississippi River

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ENGINEERING NEWS-RECORD

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FLOATING TOWER DERRICK hanging stiffening trusses and floor steel on the Davenport Bridge. The same equipment erected the bridge towers.

Building the Davenport Bridge Across the Mississippi

New toll crossing over pool above Rock Island Dam includes a 740-ft.-span suspension bridge and a series of continuous-truss spans—Suspension-bridge towers and stiffening trusses erected by floating-tower derrick

THE NEW Mississippi River crossing of the Davenport (Ia.) Bridge Commission, opened to traffic on Nov. 18, has constituted one of the substantial bridge-building operations of the year. Spanning the pool formed by the navigation dam at Rock Island three miles downstream, the bridge is divided into two parts by a narrow island that is submerged at times of high water. North of this island the structure is a twisted-wire-strand cable suspension bridge with a 740-ft. main span. South of the island are two three-span continuous-truss units supported on seven piers, each span being 222 ft. long. The approaches are of rolled-beam construction, using continuous spans.

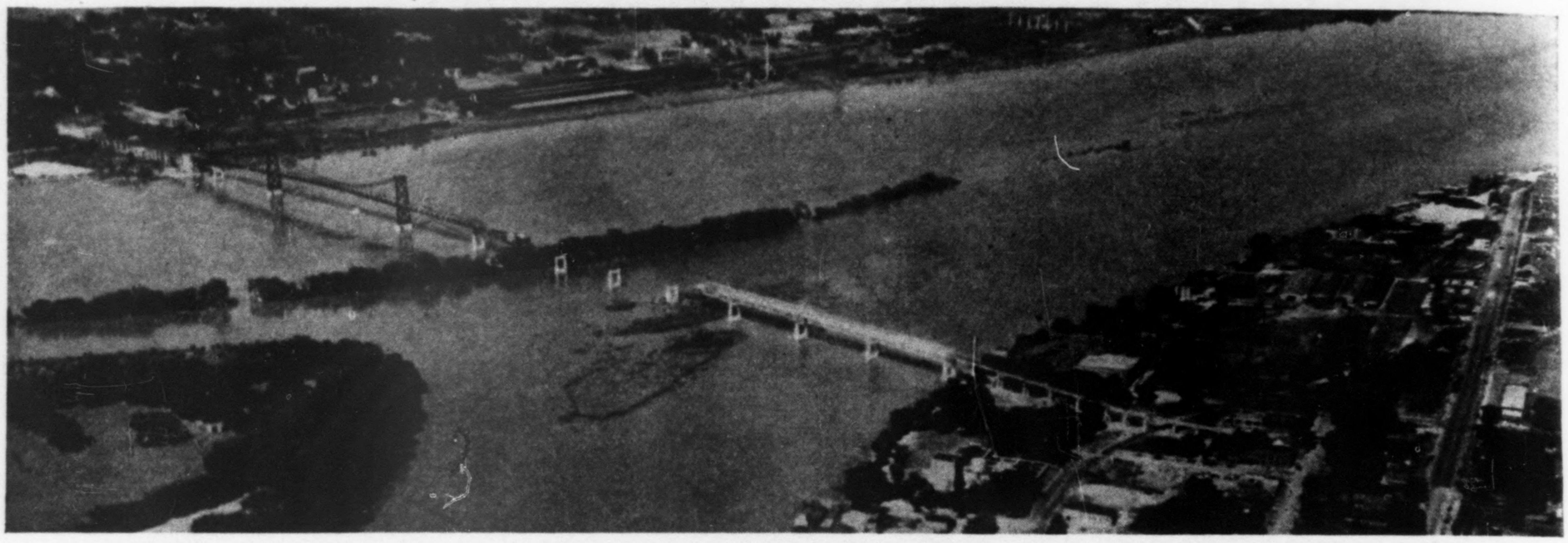
Paradoxically, neither end of the Davenport Bridge is in Davenport, the south approach coming to grade in Moline, Ill., and the north approach in Bettendorf, Ia., the Mississippi at this point running east and west. Davenport is about 3 miles downstream from Bettendorf. Projected as a toll bridge, the new crossing will accommodate two lanes of traffic on a 20-ft. roadway, which is widened in the center of the structure at the south end of the suspension bridge to accommodate the toll-collection facilities. The bridge was financed by the Public Works Administration, the total cost being about $1,500,000.

Design features

In design the bridge has several notable features. The rock foundations, which were available at relatively shallow depths, permitted the use of continuous-truss spans over the Moline Pool and continuous rolled-beam spans on each approach. Where three-span continuous-beam units are used on the approaches, they are fixed at the two intermediate piers, which are designed to deflect under temperature change.

In the bridge superstructure, considerable economy was effected by a liberal use of silicon steel and of wide-flanged rolled beams. Careful consideration was given to the design of the structural details. Lacing bars are practically eliminated in the structure, being employed only in the heavy cross-bracing of the main towers and in the columns of the cable bents.

Since the design of the towers of a



AN ISLAND marks the dividing point between the suspension bridge over the Bettendorf navigation channel and the continuous-truss bridge over the Moline Pool in the Mississippi River.

suspension bridge largely determines its appearance, particular attention was given to the proportions of these towers. They are of the fixed-base, flexible type, the tower legs consisting of rolled sections and plates, to form three vertical cells, the outer cells being varied in dimension to give the tower a curved outline when the bridge is seen in elevation. The cables for the suspended spans are of prestressed twisted-wire rope, each cable consisting of 31 strands of 1½-in. diameter and six strands of 1-in. diameter, wrapped to circular form using aluminum and zinc fillers in the interstices of the outside strands.

Construction of the bridge involved some noteworthy, although not unprecedented, practices. For example, the eleven river piers were sunk by the pneumatic method, although the water has a maximum depth of only 20 ft. and the bottom is rock. The towers and stiffening trusses of the suspension bridge were erected by a floating tower derrick more than 100 ft. high, and special jacking operations were required in landing the various spans of the continuous trusses.

Foundations

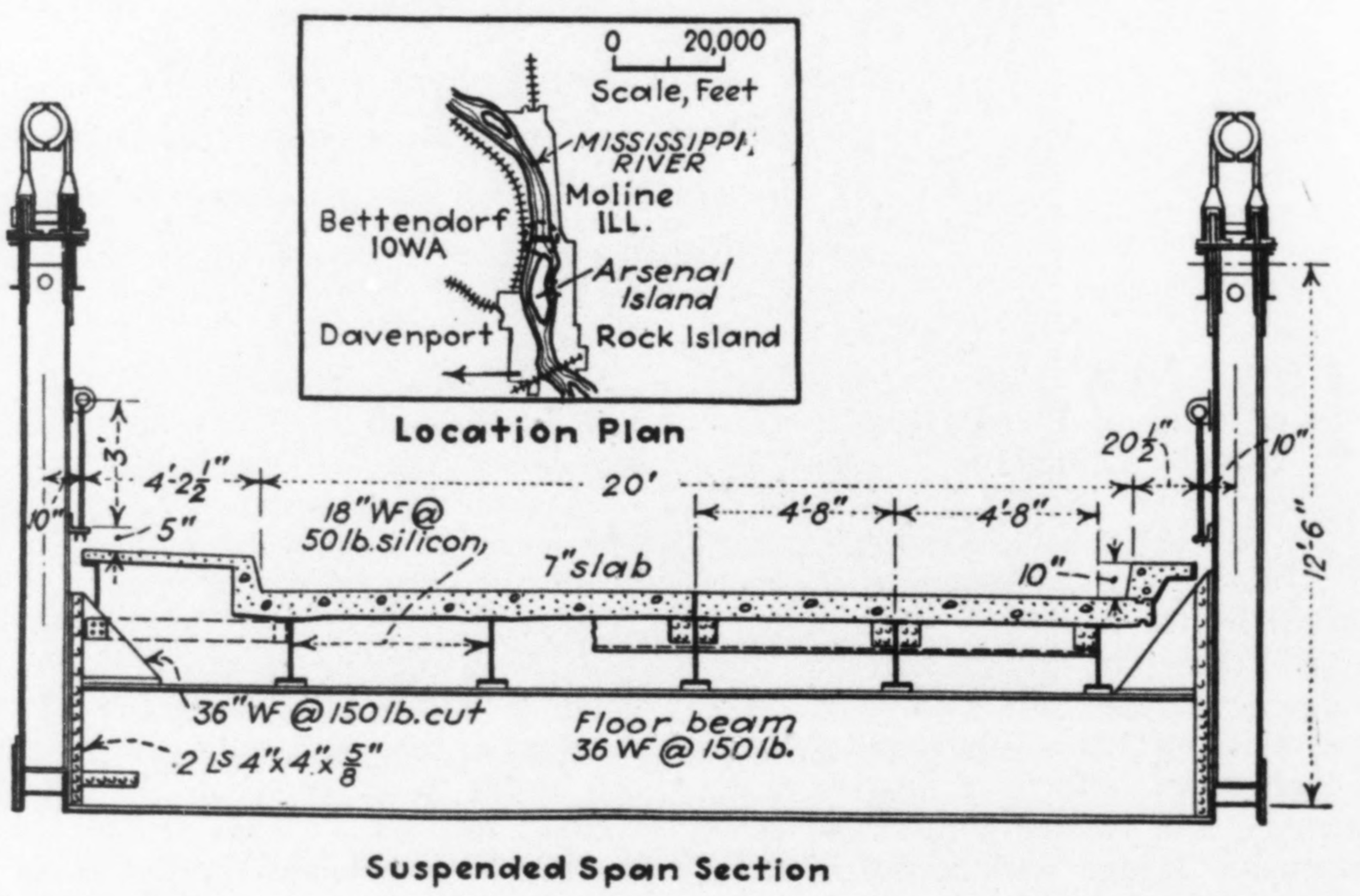
A total of 45 foundations, all carried to rock, were required for the bridge, eleven of which, including the south anchorage of the suspension bridge, are in the river. Rock is comparatively near the surface of both approaches, which permitted the footings to be built in sheeted holes of 6- to 16-ft. depth. In the riverbed the rock dips down but seldom to a depth greater than 21 ft. below water level. It is overlaid with a shallow stratum of sand. Since the rock surface was very irregular, the contractor elected to put the river piers and anchorage down by the pneumatic method in the belief that by this means better construction could be accomplished in less time than by using open cofferdams. The procedure followed is worth noting.

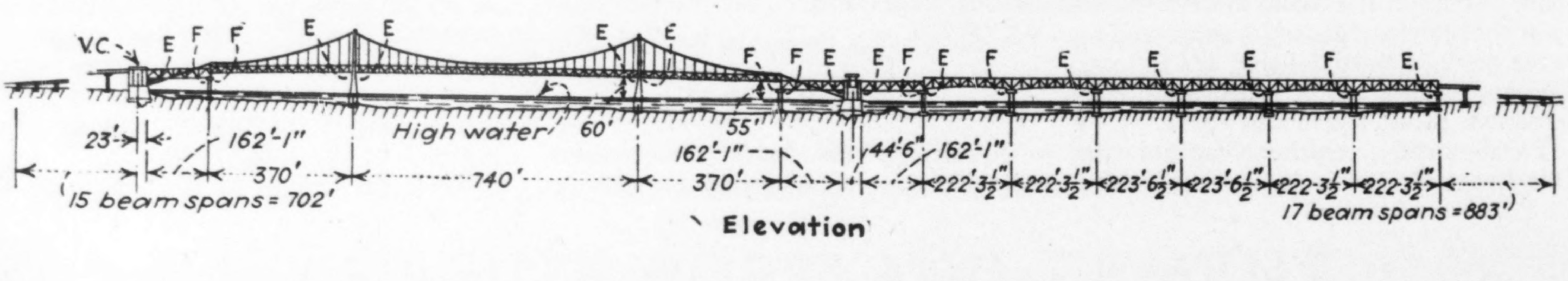
All cutting-edge sections, including about 6 ft. of steel caisson shell, were fabricated by welding in St. Louis. Launched upside down, they were towed the 250 miles up the Mississippi River to the bridge site; several of the smaller pier sections were lashed together to serve as a pontoon barge for the large cutting-edge section of the anchorage caisson. Arriving at the bridge site, the sections were turned over and raised to a fitting-up barge where the timber framework and sheathing of the top section were added. The barge was then towed to the pier location, where the caisson was picked up and lowered by a special handling device.

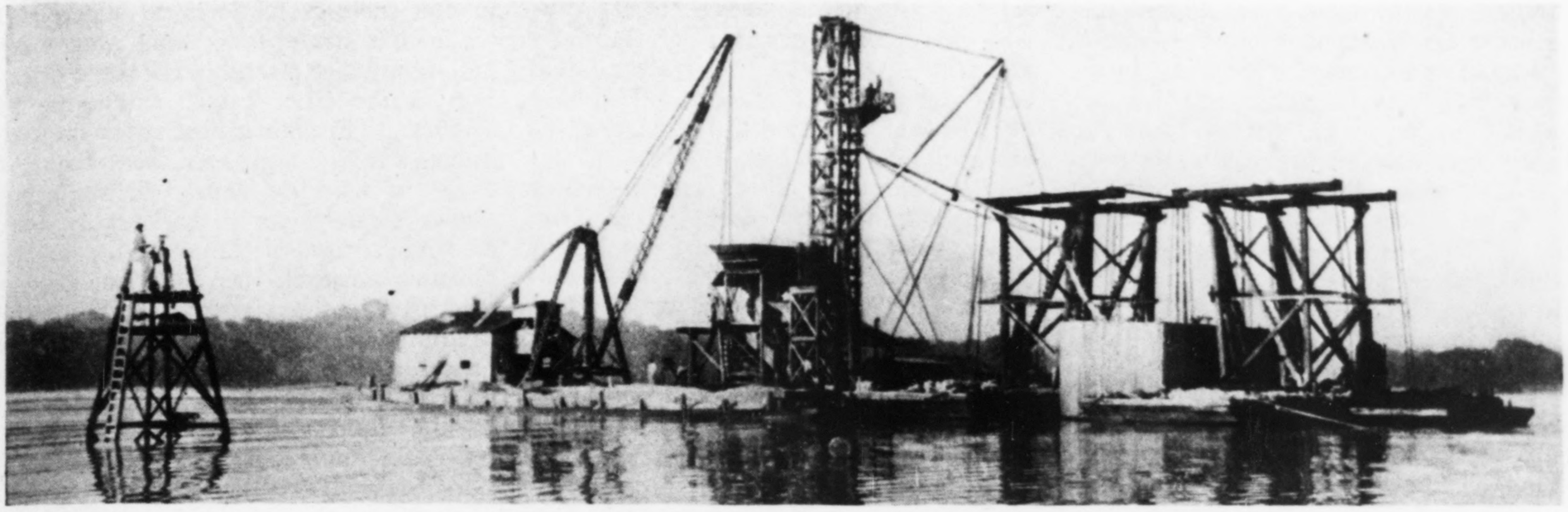
This caisson-lowering device consisted of two barges equipped with timber frames and steam hoisting engines. On top of each frame were two pairs of channels supporting sheaves for the hoist lines, which terminated in balance beams and hooks for engaging the four corners of the caisson. Each equalizing beam was supported by two seven-part lines. The barges were counterbalanced to pick 40 tons per barge. The anchorage caisson, after it was fitted with timber coffer, was removed from the pontoons by filling the latter with water, sinking them and allowing the caisson to float.

The caisson lowering device controlled the caisson until it had been landed on the river bed. Just before

ELEVATION, section and location plan of Davenport Bridge.

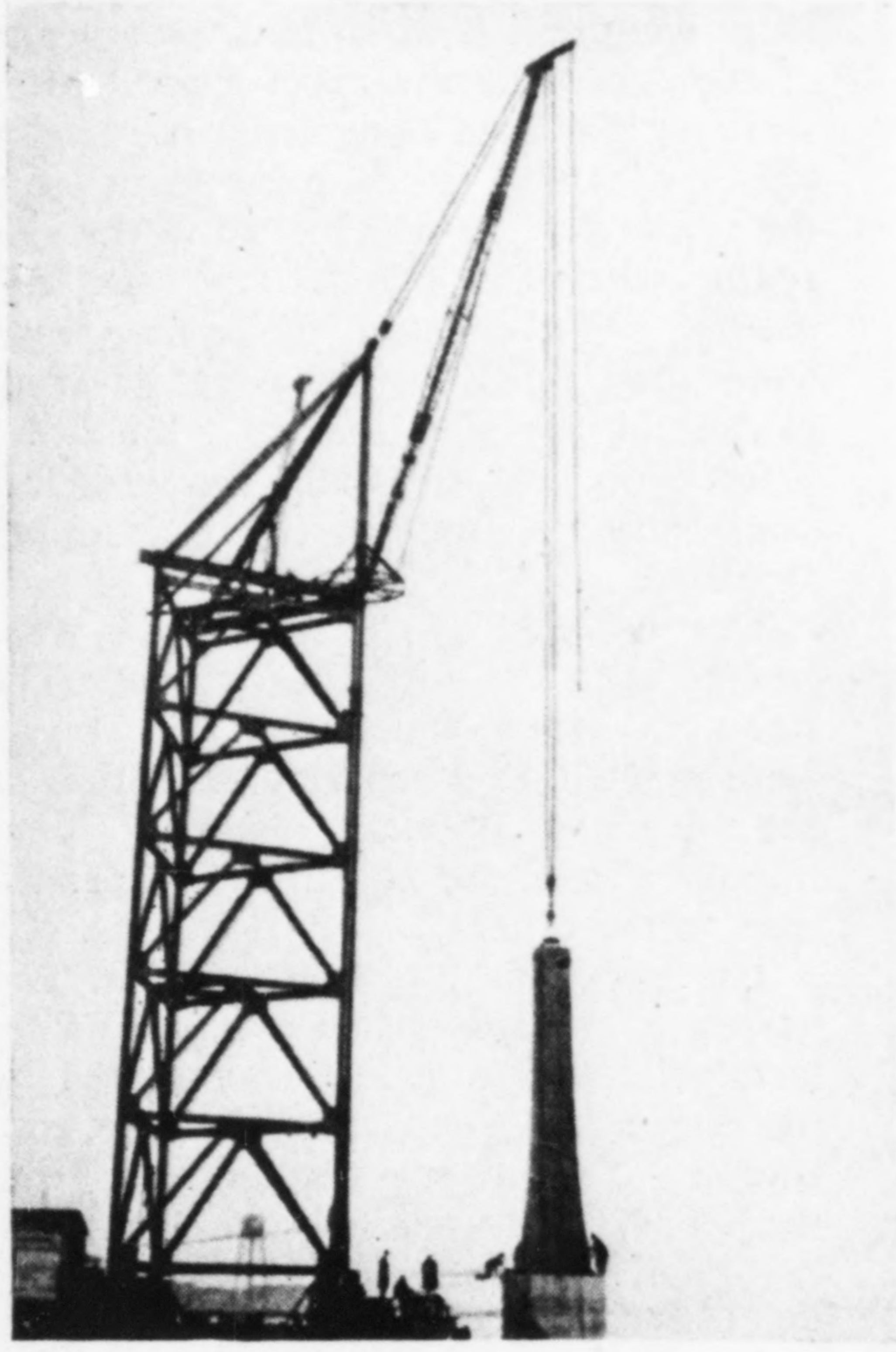






Lowering a caisson with the special headframe device.

DAVENPORT SUSPENSION BRIDGE

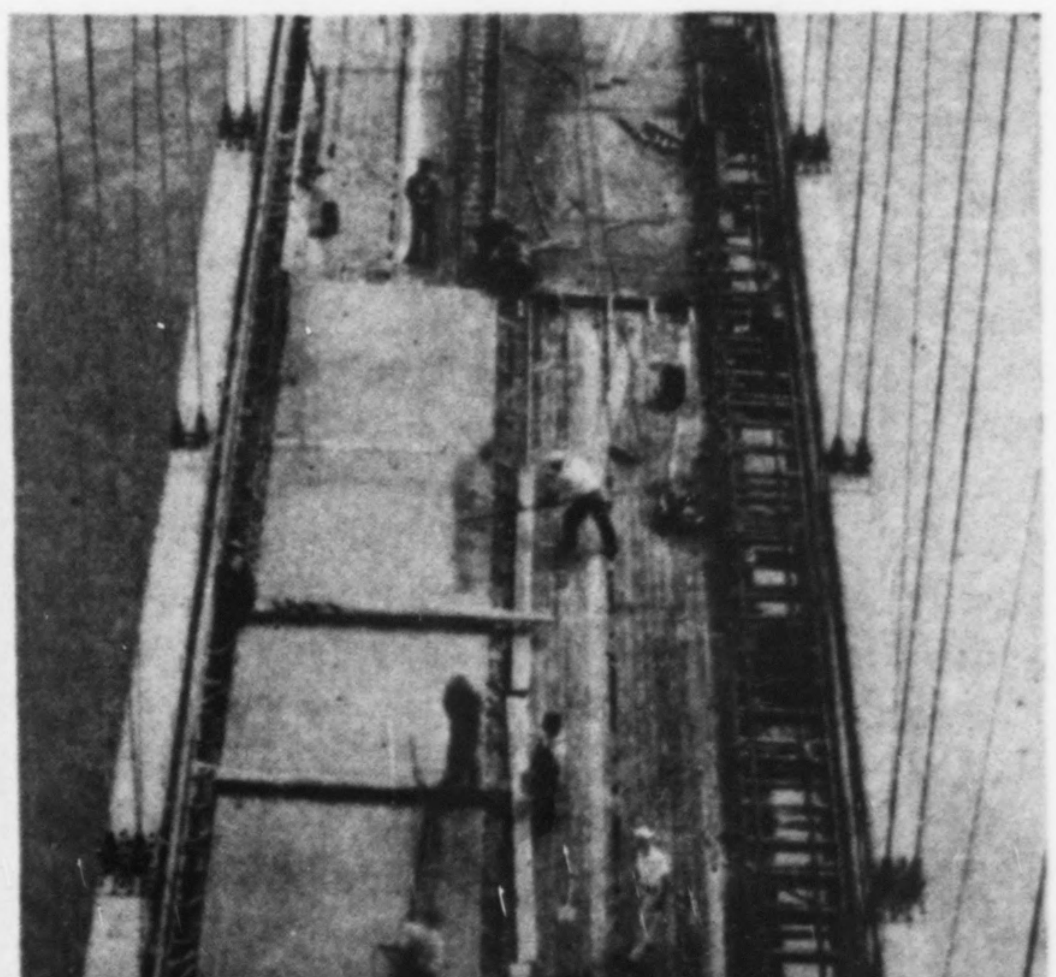


Setting tower steel.

Assembling the cable-construction equipment.

FROM PIERS TO PAVING

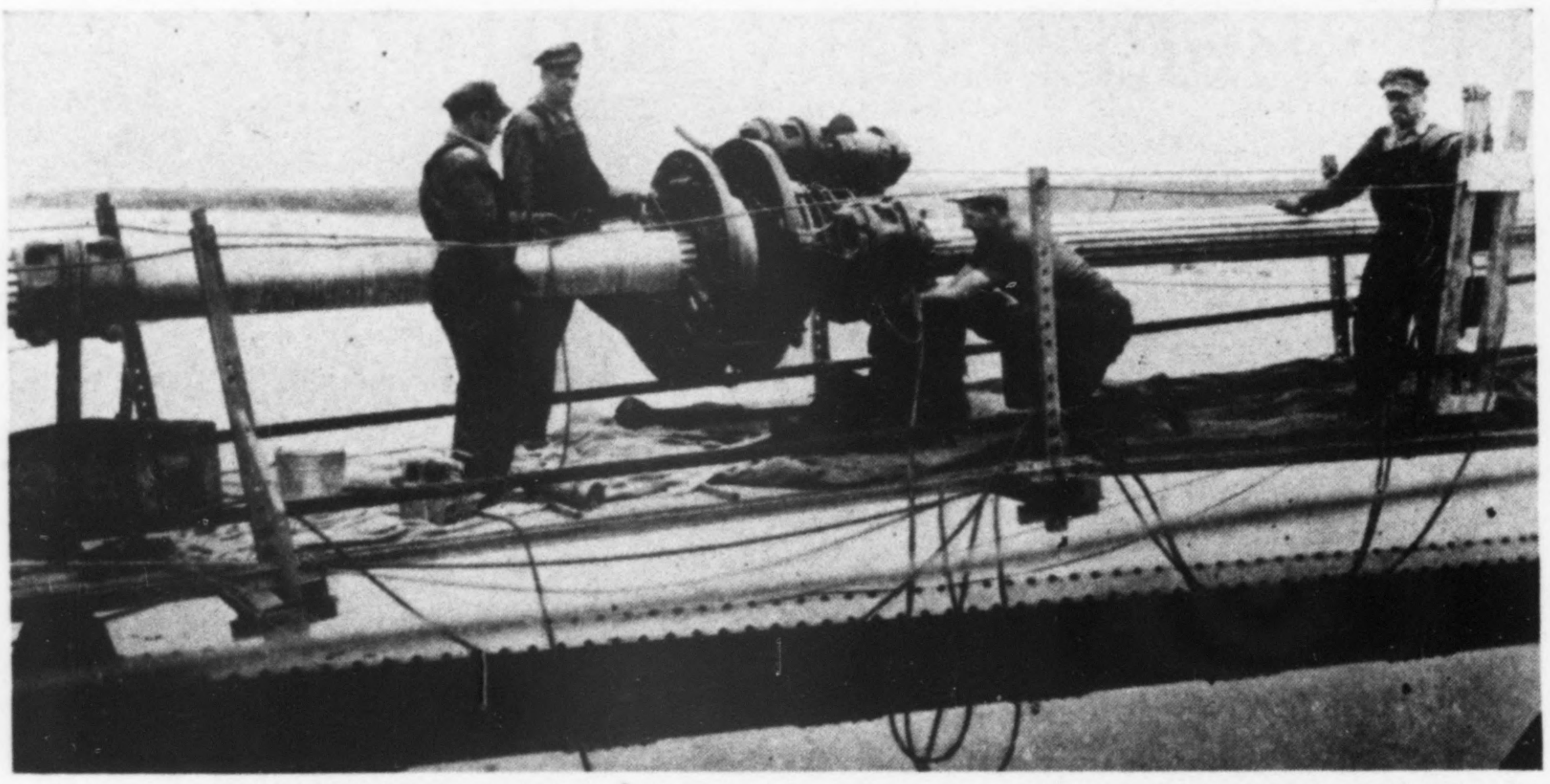
Installing floor steel in toll-collecting area over the island.



Paving being placed in checkerboard fashion.

landing the caisson was located accurately a few inches from the bottom, a transit on a triangulation tower in the river being used. At most, this adjusting to accurate location took an hour, since the caisson was under positive control by the lowering device at all times. The caisson being accurately in position, the four supporting lines were suddenly released, dropping the caisson on the bottom.

The lowering device was also used to lift the timber top sections from the river piers after they had been completed and to transfer them to the other caissons to be used over again. This method of handling the caissons proved to be both speedy and accurate.



CABLE WRAPPING beginning at center of main span. Aluminum and zinc fillers bring cable to a circular section before wire wrapping is applied.

Each pier caisson was equipped with one man lock and two material locks; a total of six locks was used on the river anchorage caisson. Excavation was partly by bucket and partly by blow pipe. A floating concrete-mixing plant was used. Foundation progress adhered closely to a predetermined schedule. Only one cavity was found in the limestone rock beneath the piers, and this cavity had been detected in the borings. The cavity was filled with concrete before sealing the caisson.

Suspension-bridge erection

The most spectacular part of the job of building the Davenport Bridge was the erection of the suspension-bridge towers and stiffening trusses by a floating tower derrick capable of setting steel nearly 200 ft. above the water level. Such equipment has been used once before—in 1931, on the bridge over the Ohio River at Maysville, Ky.—but in that case only the towers and not the stiffening trusses were erected by the tower derrick.

The Davenport tower derrick was triangular in plan, 33 ft. on a side and 112 ft. high above the two steel barges on which it rested. On top of the tower a 35-ton steel stiff-leg derrick with 90-ft. boom was erected. The barges, 30 ft. wide by 130 ft. long by 7½ ft. deep, had an average draft of 4.25 ft. with a 30-ton load in the derrick falls. In designing the equipment extreme care was exercised in determining the draft and trim of the boat under all possible sizes and positions of loads. The base of the tower consisted of two plate girders spanning from barge to barge and resting on two 36-in. rolled beams placed lengthwise of each barge. One plate girder supported the front leg of the tower, while the other girder carried the two rear legs. Two counterweights of 50 and 85 tons, respectively, were used on each barge.

The derrick was operated by a three-drum steam hoisting engine and a swing engine. A six-part falls and a thirteen-part topping lift were used.

The Davenport suspension bridge has a main span of 740 ft. and suspended side spans of 370 ft. Between the cable bent pier and the anchorage on each side is a 162-ft. deck span. Erection began with the towers, the steel being brought out from a Bettendorf storage yard on barges. With the tower complete, the 162-ft. Bettendorf approach-span trusses, weighing 41 tons, were set without falsework, using a locomotive crane on the shore end and the tower derrick for the end at the cable bent. The trusses were spliced in the air while hanging from the hoist lines. A similar truss on the east end of the bridge was spliced on barges and erected entirely by the tower derrick.

Work was shut down Dec. 21 because of heavy ice in the river and was not resumed until March 20, although most of the Bettendorf approach work was completed during the winter months. When work was resumed in the spring, everything was ready for cable construction. The hauling-rope supports on top of the main towers had been placed previously, and the first operations, therefore, consisted of installing the hauling rope and erecting the footwalks and storm cables. After the guide strands in the cable were placed and adjusted and the pull-back cables were attached to the towers and cable bents, erection of the strands of the cables was carried out in the usual way, the hauling rope pulling a strand in one cable from north to south, and while that strand was being pinned off pulling another strand in the same direction in the other cable. Stringing of 37 strands in both cables, after the two guide strands had been set, required only six working days. Stringing of twelve strands, six in each cable, took on an average of 220 minutes in the morning of each day. A small gang was used in the afternoon to make the preliminary adjustments, while the final adjustment of each layer of strands was made between midnight and 5 a.m., to allow stringing the next layer the following morning. Cable-band erection required two days, and suspenders were hung as necessary by the floating tower derrick at the time the stiffening trusses were erected.

Hanging the stiffening trusses, which were fabricated in sections 50 to 80 ft. long, weighing 8 to 13 tons, was begun at the center of the main span. After sections had been hung from the twelve center panels of the 30-panel main span, the tower derrick was moved to the side spans where it erected the six end panels. The ends of the center span were then filled in, followed by completion of the side spans. This order of erection kept the main tower deflections within a limit of 12 in. in either direction.

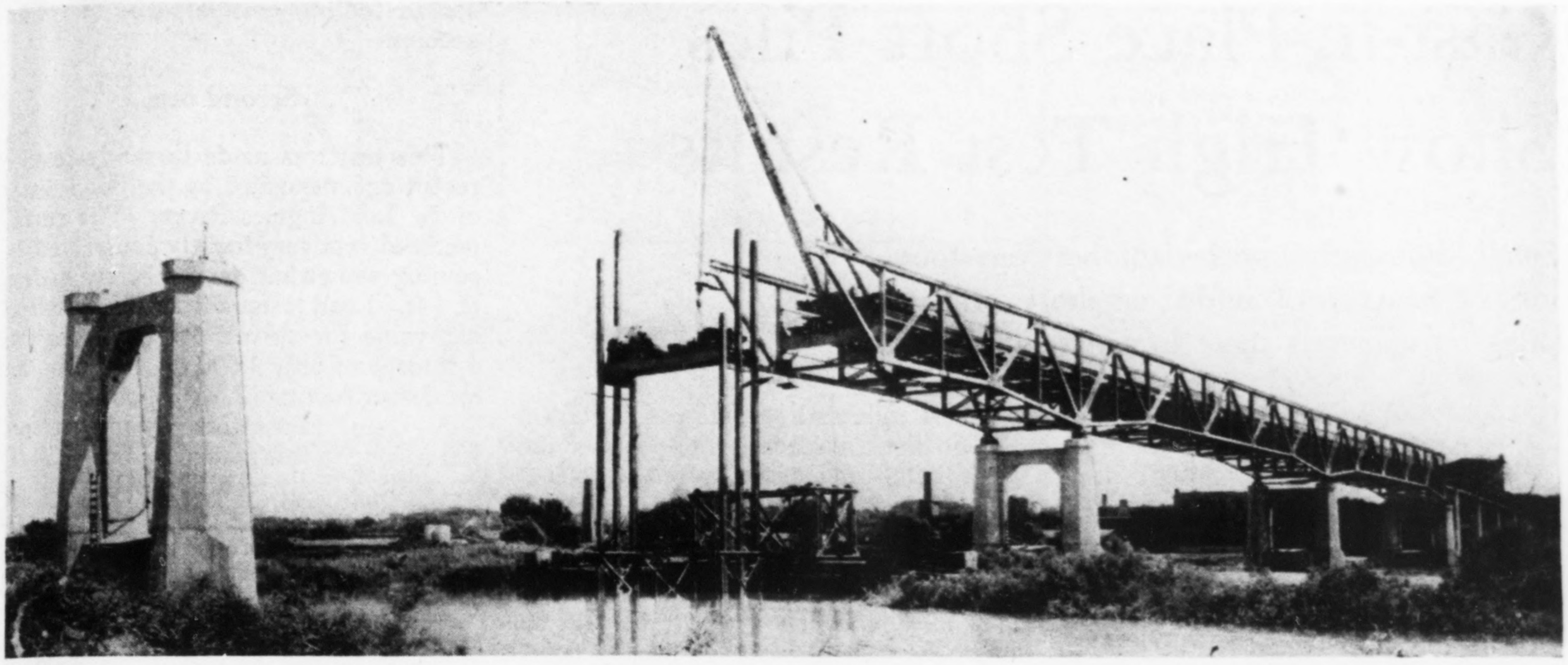
The majority of the floorbeams were erected with the stiffening trusses. The stringers, sidewalk framing and railing were erected as a separate operation of the floating derrick, working continuously from one end of the suspended span to the other.

The program for steel erection and paving of the suspension bridge was determined from a model constructed by the engineering department of the contractor. The program worked out from the model was used without change in the field. Model studies gave figures on tower deflections, cable elevations and cable distortions for any loading and with sufficient accuracy for planning the field work, and the use of a model saved many hours of laborious computation.

All rivets except the top-chord splices were driven in the suspension bridge before the paving was laid. Pavement concrete was poured in checkerboard pattern in blocks 100 ft. long and 10 ft. wide (one-half roadway width), to keep tower deflections and distortion of the stiffening trusses within reasonable limits. The concrete was distributed from the Bettendorf mixing plant in trains of four ½-yd. hopper cars pulled by a narrow-gage gasoline locomotive on tracks laid in the sidewalk area. Following completion of the paving, the cables were wrapped and the footwalks removed, completing the suspension bridge.

Continuous-truss erection

The two three-span continuous-truss units of half-through construction, com-



CANTILEVER ERECTION of continuous-truss spans using a falsework bent of six steel H-piles equipped with jacks to lift the span for landing on pier ahead.

prising the south half of the bridge called for some special erection procedure, since it was desired to erect the spans by the cantilever method. The continuous units were designed as a series of simple spans for steel dead loads and later made continuous for the roadway slab and live load. Since there was little clearance between the ends of the trusses over the piers, it was not possible to anchor the trusses sufficiently to erect by the cantilever method in a position higher than the final position. As an alternative, adjacent spans were tied together for tension only by means of straps along the web of the top chords, and the projecting cantilever ends were allowed to droop until they could be picked up at the falsework bents on jacks. Erection began at the south end, the steel being unloaded under the Moline approach, lifted to small trucks on the deck and hauled out to the erection traveler. This traveler was made only 12 ft. wide, to allow the steel to be delivered alongside by standard-gage gasoline dinkey and trailers. The traveler consisted of a small stiff-leg derrick mounted on a steel platform equipped with flanged wheels for operating on two 85-lb. rails laid directly on the stringer flanges. It carried a two-drum gasoline hoist.

Falsework consisted of towers of six steel H-piles braced at about water level by a steel-frame cage about 12 ft. deep and above this by a crossbracing of wire cable extending to the jacking girders upon which the trusses were supported. The pile flanges were punched with a series of holes, to permit the girders to be attached at a convenient level. The bracing cage and piles were moved from span to span on a barge. Lifted from the barge by the deck traveler, the piles were set in the frame and lowered to the bottom of the river, where they were driven as far as possible into the rock. A 2,000-lb. drop hammer was used, handled by an air hoist, since there was no whip line on the traveler engine; the swinging hammer leads were handled by the main falls.

Two complete six-pole bents were provided, since three falsework supports were required under the first span. The procedure was to set falsework bents under the second and fourth panel of the south span, erect these four panels, remove the bent under panel point 2 and transfer it to panel point 6, after which the span was completed by cantilevering to the next pier. With this span in place as a beginning anchor, the other five spans were each cantilevered for six panels (134 ft.), landed on a six-pile bent and again cantilevered 88 ft. to the next pier. One 250-ton hydraulic jack in combination with wood-camber blocking was used under each bottom chord on the falsework jacking beam. Depending on conditions, it was necessary to jack up from 10 to 14 in., after landing on the falsework, to get high enough to land on the pier ahead. The bottom-chord section adjacent to the piers had to be increased somewhat in section since the cantilever stress was higher than the design stress. Also, one truss diagonal over the falsework bent was temporarily strutted to increase its stiffness and hence its capacity.

The last four 220-ft. spans, weighing about 190 tons, were erected in an average of 60 working hours each (minimum, 55 hours), this time including erection and removal of the falsework bents. The maximum load handled by the traveled was the pile cage, which weighed 6½ tons at about 45-ft. reach. The piles were pulled with the traveler main falls aided by compressed-air jetting where the penetration was from 10 to 12 ft. in mud and clay overlying rock.

The work was done in two six-hour shifts per day, five days per week. All men except the supervisory forces were employed through the National Re-employment Service at Davenport and Rock Island.

The bridge was designed and its fabrication and erection were supervised by Modjeski, Masters & Case, Inc., consulting engineers, Philadelphia, with W. C. Gorman as resident engineer.

The substructure contract was carried out by the Kansas City Bridge Co., I. E. Hayes, superintendent. Fabrication and erection of the superstructure were handled by McClintic-Marshall Corp., for whom H. E. Crider is manager of erection, Western District; L. L. Martin was resident engineer.

Electric Rate Survey Standardizes Definitions

Confusion in terminology used in electric rate schedules and contracts throughout the United States has led to the preparation of a glossary of 161 definitions by engineers and accountants of the Electric Rate Survey now being conducted under the direction of the Federal Power Commission. This is being checked by a selected group of utility and regulatory officials, engineers and other experts for criticism before publication.

Need for a glossary developed during the study of reports from operating utilities. It was found that that there is no community of understanding regarding numerous terms used in rate schedules and contracts, although the amount of the customer's bill was often materially affected by the interpretation of a term to which no definite meaning could be assigned. Although the glossary was prepared primarily for its own use, the Electric Rate Survey believes that publication will help to eliminate the confusion prevailing in rate and power terminology.